997

Issued June 18, 1907.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN 295.

POTATOES AND OTHER ROOT CROPS AS FOOD.

[CORRECTED TO APRIL 8, 1910.]

BY

C. F. LANGWORTHY, Ph. D.,
In Charge of Nutrition Investigations, Office of Experiment Stations.

PREPARED UNDER THE SUPERVISION OF THE OFFICE OF EXPERIMENT STATIONS,
A. C. TRUE, Director.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Office of Experiment Stations,
Washington, D. C., April 24, 1907.

Sir: In connection with the nutrition investigations of the Office of Experiment Stations, a number of studies have been made of the nutritive value and digestibility of potatoes and other root crops and the losses which such foods sustain when cooked in different ways. Many analyses of such foods have been made and other questions connected with their place in the diet and their most economical use in the home have received attention at several of the agricultural experiment stations.

The results of such investigations and the general information available in scientific journals and other works of reference have been summarized in the preparation of the present article on potatoes and other root crops used as food, by C. F. Langworthy, in charge of Nutrition Investigations of this Office, which I have the honor to transmit herewith and recommend for publication as a Farmers' Bulletin.

The article is similar in purpose to other popular summaries which have appeared in this series of bulletins. The section which concerns potatoes is a revision and extension of an article by Doctor Langworthy, published in the Yearbook of the Department for 1900.

Respectfully,

A. C. True,
Director.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

POTATOES AND OTHER ROOT CROPS AS FOOD.

INTRODUCTION.

Among the products of the vegetable kingdom used for human food the cereals are undoubtedly the most important, but next to them must be placed the group of plants which during the favorable days of summer lay up for themselves a supply of reserve material in thickened roots or underground stems and bulbs. These plants belong to many different groups and have different habits and varied appearance, but from the standpoint of food value their common characteristic of producing underground parts filled with nutritious material makes it convenient and logical to group them together. In some cases it is a true root, such as the beet, in which the plant lays up its store; in others it is an underground stem as in the case of tubers like the potato, and again it is a bulb like the onion. Botanically, these distinctions are very important, but they have little bearing on the food value, and for the present purpose it is sufficiently accurate to speak of all such vegetables as "root crops."

These edible tuberous bulbs and roots divide themselves roughly into two main classes: Those in which the plant stores its food principally in the form of insoluble starch, and those in which a comparatively large proportion is in the form of sugar or some other soluble bodies. As a general rule vegetables of the latter group contain a larger proportion of water than the starchy tubers, etc., and are therefore often called the succulent roots.

Of the starchy group, the common potato is by far the most important as regards both its nutritive value and the extent of its cultivation. In the United States the sweet potato ranks next to it. What a prominent place these two together hold in the diet may be seen from the fact that in the average of 376 American dietary studies they were found to furnish 12.5 per cent, or about one-eighth of the total food material, and 8.3 per cent, or about one-twelfth of the carbohydrates. All other vegetables together furnished only 7.8 per cent of the total food and 3.7 per cent of the carbohydrates. There are no starchy tubers or roots except these in general use in this country, though a few are frequently seen in city markets. In other parts of the world, especially in eastern Asia and the Tropics, others to a large extent occupy the place which potatoes hold in Europe and America.

The succulent roots are less important as human food than the starchy ones. Beets, carrots, parsnips, turnips, and onions are the most common. Many of them are characterized by strong flavors and odors due to volatile oils which they contain. Like potatoes, they can be stored for months without serious deterioration, and being comparatively low-priced occupy an important place in the list of winter vegetables. Some highly flavored roots, such as the horse-radish and ginger, serve mainly as condiments, their food value in the quantities in which they are used being too small to be of any practical importance.

The tubers and root vegetables may roughly be said to contain from 70 to 90 per cent water and from 10 to 30 per cent solid material. By far the greater part of the solid matter occurs in some form or forms of carbohydrates. There are also small quantities of nitrogenous substances, and, compared with most food materials, considerable quantities of mineral matters or ash, especially in the succulent roots. From this it will be seen that even the least watery of these vegetables is far from supplying the body with all that it needs. The carbohydrates furnish it with excellent fuel for keeping up its warmth and supplying it with energy needed for muscular activity. The ash and the various compounds which give flavor supply the needed mineral matters and stimulate the action of the digestive organs, but protein or nitrogenous material, which is indispensable in the building and repair of muscular tissue, is in most varieties nearly lacking, and in no case is it in the right proportion to nonnitrogenous material to serve for the best bodily development. Much is said about the Irish peasant and his potato diet and how well he can live and work on this fare, but in almost every case he keeps a cow along with his potato patch, and the abundance of milk in his diet furnishes him with a fair amount of protein. There is every reason to believe that among the tropical races, who are supposed to live mainly on the starchy roots and similar foods, there are some such sources of protein in the diet which general observers have overlooked. For instance, few travelers who write of the general use of rice in the Orient realize the importance of the nitrogenous soy-bean products so extensively used in China and Japan, or the milk, milk products, pulse, or legumes, and similar foods used in India. It is in connection with other materials richer in protein that the edible tubers and roots find their true place in the diet.

The potato so far surpasses all other tubers and roots in importance that its composition and nutritive value have been carefully studied both in this country and in Europe. It will, therefore, be discussed in detail and in a measure considered as a type of all the other tubers and roots, especially the starchy group.

7

POTATOES.

HISTORY AND EXTENT OF CULTIVATION.

The potato, called in different regions white potato, Irish potato, English potato, or round potato, was first introduced into Europe between 1580 and 1585 by the Spaniards, and afterwards by the English about the time of the expeditions sent by Raleigh to the Virginia country. It is believed to be a native of Chile, where a wild plant is still found which much resembles it. A similar tuber, known as the Cetewayo potato, is also eaten by the natives in some districts of South Africa. When first visited by Europeans, the aborigines in Chile and adjacent regions cultivated the potato for its edible tubers and had apparently long done so. It was probably introduced into the United States, especially into Virginia and North Carolina, toward the end of the sixteenth century. In spite of its easy cultivation, rich yield, and pleasant flavor, the potato did not receive a warm welcome when first introduced into Europe. For a long time there was a popular belief that it was poisonous, perhaps because botanically it is related to the deadly nightshade, and for years it was cultivated mainly as a garden curiosity. During the second half of the eighteenth century, however, came a series of bad harvests in some of the staple food crops throughout Europe and the potato quickly rose into almost universal prominence. Since then its use has constantly increased, for it is one of the cheapest vegetables to raise, can be kept over the winter, is easy to prepare for the table, pleasant in taste, and very rich in digestible starch. It soon became a staple food among all classes throughout central and northern Europe, so that when in the middle of the last century the black rot wrought its deadly havoc on the crops not only Ireland but large districts in continental Europe also were seriously threatened with famine. Next to the breadstuffs it is undoubtedly the most important food crop of the western nations.

According to the last United States census, 273,318,167 bushels were raised in this country in 1899, representing 40.7 per cent of the total vegetable crop, and valued at $98,380,110. Of course, part of the total crop is used for animal fodder and a part for various manufactured articles, but the proportion thus used is probably small, and includes mainly inferior grades of tubers. The principal article manufactured from potatoes is starch, which, until cornstarch supplanted it, was quite largely used in cooking, but now is mainly employed for making sizing for paper and textiles and for other technical purposes. Potato starch has also been sometimes found as an adulterant of fine flours and starches. Much of our commercial glucose is made from potatoes, and they are also an important source of alcohol, especially in Europe.

It is a fact worthy of mention that, as the potato has been modified by cultivation, it has largely lost the power of producing seeds, and the cultivated potato differs from the wild in seldom producing seed-bearing fruits. This is a disadvantage from the plant-breeder's standpoint, as he depends on seed from blossoms properly fertilized to yield new varieties. From the grower's standpoint it is of little moment, as he always uses the old tubers in planting the potato crop, each "eye" in the potato being a bud on the underground stem which is capable of growing into a new plant.

The potato is grown in practically all parts of the United States, but most abundantly in the North Atlantic and North Central States. Within recent years its culture has been greatly developed throughout the sandy pine tracts just south of the Canadian boundary, and local experiment stations have given great aid and encouragement to the work. The South Atlantic States furnish a considerable proportion of the crop, but mainly in the form of high-priced early potatoes for city markets.

STRUCTURE AND COMPOSITION.

The potato tuber, as has been said, is in reality a modified stem, being shortened and thickened as a storehouse for material held in reserve for the early growth of new plants. The outer skin of the tuber consists of a thin, grayish brown corky substance and corresponds roughly to the bark of an overground stem. If a crosswise section of a raw potato is held up to the light three distinct parts besides the skin may be seen. The outermost one is known as the cortical layer and may be from 0.12 to 0.5 inch in thickness. This layer is slightly colored, the tint varying with the kind, and turns green if exposed to the light for some time, thus showing its relation to the tender green layer beneath the bark of overground stems. It is denser than the other parts of the potato and contains many fibro-vascular bundles, especially on the inner edge where a marked ring of them plainly separates this layer from the next. The interior or flesh of the tuber is made up of two layers known as the outer and inner medullary areas. The outer one forms the main bulk of a well-developed potato and contains the greater part of the food ingredients. The inner medullary area, sometimes called the core, appears in a cross section of the tuber to spread irregular arms up into the outer, so that its outline roughly suggests a star. It contains slightly more cellulose and less water and nutrients than the outer medullary portion. These four parts of the tuber are shown in figure 1.

As in all other plant forms, the framework of the tuber is made up of cellulose, a carbohydrate or group of carbohydrates familiar in many forms, as, for instance, the fiber of cotton or linen or the bran

of wheat. In food and feeding stuff analyses it is usually designated crude fiber. Cellulose forms the walls of a network of cells, which in turn form the body of the tuber. These cells vary in shape and size in different sections of the tuber according to the part they play in its life. In the flesh they serve mainly for storage, and in them lie the starch grains. (See fig. 3*a*.)

The interior of the tuber is more or less permeated by water in which are dissolved nearly all the soluble ingredients, including the various soluble carbohydrates,[a] mineral matters, and soluble proteid bodies.

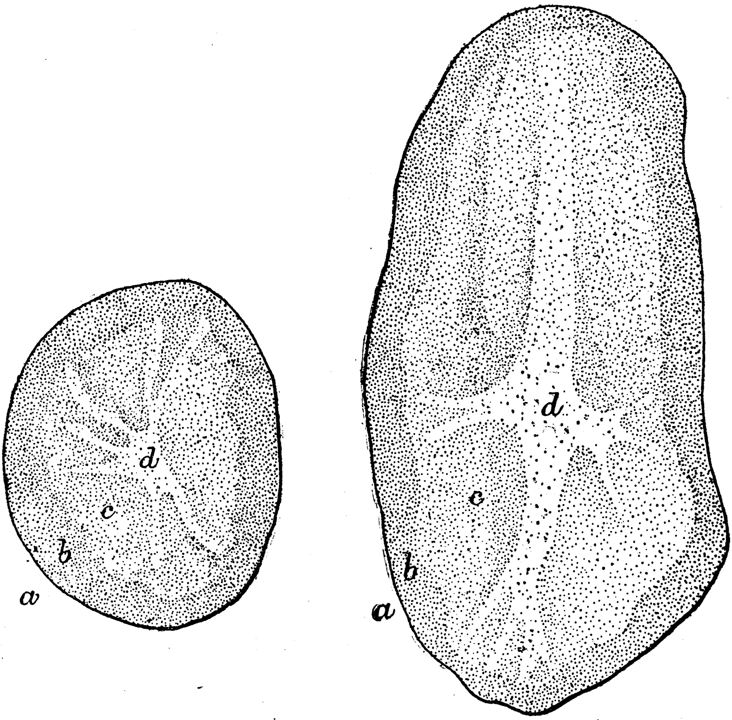

FIG. 1.—Transverse and longitudinal sections of the potato: *a*, skin; *b*, cortical layer; *c*, outer medullary layer; *d*, inner medullary area.

Cultural varieties of a given plant often have very different habits, appearance, and quality, and it is natural that the amounts and proportions of water, carbohydrates, fats, protein, and mineral matters which the potato contains should vary with the variety as well as with the character of the soil, the climate, and other conditions under which it grows. Moreover, since the needs of the potato plant vary at dif-

[a] In this connection it is well to recall that the carbohydrates (cellulose, starch, the different kinds of sugars, etc.) are all closely related, and that under the influence of certain acids, heat, or other agency an insoluble form, such as starch, may be changed into a soluble form, or vice versa.

ferent stages of its developement, it will provide for them by varying the ingredients stored in the tubers and elsewhere. Taking into account all these factors, it might seem impossible to make any general statements about the chemical composition of the potato, but it may be said that the variations are in degree rather than in kind, and so many analyses and studies have been made, both in this country and in Europe, that the average or general characteristics of the potato are now well established. The figures in Table 1 show the composition of raw and cooked potatoes and represent the average of many American analyses. For comparison the composition cf white bread is also given.

TABLE 1.—*Composition of raw and cooked potatoes.*

Kind of food.	Refuse.	Water.	Protein.	Fat.	Carbohydrates.		Ash.	Fuel value per pound.
					Sugar, starch, etc.	Crude fiber.		
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
Potato, as purchased	20.0	62.6	1.8	0.1	13.8	0.9	0.8	310
Potato, edible portion		78.3	2.2	.1	18.0	.4	1.0	375
Potato, boiled		75.5	2.5	.1	20.3	.6	1.0	440
Potato, mashed and seasoned		75.1	2.6	3.0	17.8		1.5	505
Potatoes fried in fat, "Potato chips"		2.2	6.8	39.8	46.7		4.5	2,675
Potato, evaporated		7.1	8.5	.4	80.9		3.1	1,680
White bread		35.3	9.2	1.3	52.6	.5	1.1	1,215

The corky skin of the potato makes up about 2.5 per cent of the whole, and the cortical layer 8.5 per cent, leaving 89 per cent for the medullary areas. Theoretically, the skin is the only refuse or inedible material in the potato, but in practice a considerable part of the cortical layer is usually removed with it. When the surface is irregular or lumpy or the tubers have shriveled in storage, a much greater proportion of the flesh is likely to be cut off with the skin in peeling than is the case when the tubers are smooth and in good condition. When potatoes are baked or boiled in their jackets, more or less of the flesh is wasted when the skin is removed, and in this case also the amount bears some relation to the shape of the tubers. Just how much such a loss of edible portion averages it is hard to say. In connection with the nutrition investigations of this Department, it was estimated that in peeling raw potatoes the loss was about 20 per cent, which would include not only all of the skin and the cortical layer, but also 9 per cent from the flesh. When we recall how large is the proportion of water and how low that of nutrients in the tuber, and also that the larger proportion of the valuable protein and mineral matters is in the outer layers, this waste appears more important than is generally realized.

The edible portion of the potato, i. e., the tuber without the corky skin, holds on an average about 78 per cent water, and so only about

20 per cent of the whole tuber has a direct food value. Figure 2 represents the composition of the potato in graphic form and shows the proportion usually wasted when it is boiled.

This diagram shows very plainly that the bulk of the potato tuber is water. The stage of growth and other conditions affect the proportion present, young tubers being more juicy or watery than those which are fully developed. When potatoes are stored, they undergo a shrinkage chiefly owing to loss of water or juice by evaporation. According to tests made at the Michigan Agricultural Experiment Station this loss amounted to 11.5 per cent when they were kept in storage from September 30 to May 1.

The carbohydrates are by far the most abundant of the nutrients. Of the 18.4 per cent present less than 0.5 per cent is made up of cellulose, yet one sometimes hears the statement made that potatoes are indigestible on account of the large quantities of cellulose which they contain. In reality there is as much or more in almost all the cereals and other vegetable foods, and such a criticism of the potato has no warrant of fact.

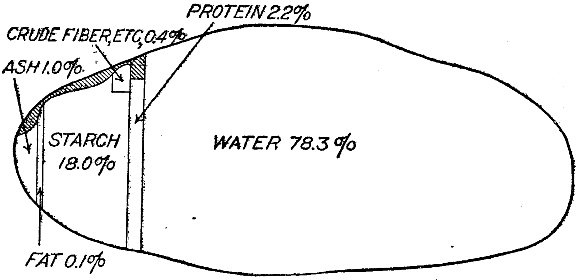

FIG. 2.—Composition of the potato. The shaded portion represents the average loss of nutrients when boiled.

The bulk of the carbohydrates which the potato stores for future use is in the form of starch, which is, of course, insoluble in cold water, and small quantities of such soluble carbohydrates as dextrose, sugar, etc. In young tubers there is a larger proportion of sugars and less starch than when they have become mature. As the tuber lies in the ground the starch content increases. When it begins to sprout, however, part of the starch is converted by a ferment in the tuber into soluble glucose. Thus, young or early potatoes and old ones both have a smaller proportion of starch and more soluble sugars than well-grown but still fresh tubers. If the grated potato is mixed with water starch falls out from the broken cells and settles to the bottom of the vessel, and may be removed in the form of a white deposit. Starch is manufactured to a large extent from potatoes by methods which are similar to the above in principle.[a]

Other carbohydrates in the potato are the so-called pectose bodies, the substances which cause fruit jellies to stiffen, and when the tubers are large and pulpy pectoses may make up 4 per cent of the tuber,

[a] For an extended account of the manufacture of starch from potatoes, see U. S. Dept. Agr., Bur. Chem. Bul. 58.

though they usually occur in much smaller quantities. They are believed to have about the same food value as starch.

Fat, or ether extract, appears in such small quantities in potatoes that it may be practically neglected in discussing their food value, especially as the greater part occurs in the inedible skin in the form of a wax-like body.

The protein bodies are rather scanty, as compared with those of cereals and such vegetables as peas and beans. Only about 60 per cent of the total amount present is true protein—that is, in a form which can be used for the building and repair of body tissue. This means that a pound of potatoes furnishes only about 1.3 per cent or 0.2 of an ounce of true protein, and emphasizes the statement already made that potatoes alone make a very incomplete diet, as the proportion of nitrogenous material would be very small in a quantity sufficient to supply the body with all the energy-yielding material required.

These potato proteids have been studied by the Connecticut Experiment Station and found to consist of a form of globulin, for which the name "tuberin" is suggested, and a proteose, part of these nitrogenous constituents being dissolved in the juice and part stored with the starch in the cells, especially in the cortical layer.

The nonproteid forms of nitrogenous substances in the potato are asparagin and small quantities of amido acids, occurring mostly in the juice. If they have any food value it is indirect and due to the fact that they protect the true proteids from waste during digestion. It is possible that they may aid digestion in some way or serve a similar purpose. There is a larger proportion of protein compounds, and especially of the more soluble forms, in young potatoes than in old.

The most important mineral matters found in potatoes are potash and phosphoric acid compounds. There are several organic acids (as citric, tartaric, and succinic acid), which vary in tubers of different ages and account in some measure for the flavor of potatoes. (See also p. 19.)

If peeled potatoes are exposed to the air the outer surface turns brown, just as does the flesh of many fruits. Such change is due to the action of enzyms or unorganized ferments naturally present in the plants. In the presence of the oxygen of the air they work upon tannin-like bodies in the tuber or fruit in such a way that the latter change color. In the case of potatoes this browning may be prevented by putting the peeled tubers into salted water or even into cold plain water.

In the condition in which they are purchased potatoes resemble such succulent carbohydrate foods as turnips and beets, with an average water content of 90 per cent, more than they do such dry carbohydrate foods as flour or rice, with an average of 12 per cent. The

condition in which foods are eaten should also be taken into account, for if the value of a food is judged solely by its chemical composition as it is found in the market a wrong impression may be obtained. For instance, potatoes as purchased consist of one-fifth and rice of seven-eighths nutritive material. The first inference is that rice is more than four times as nutritious as potatoes. In one sense this is true—that is to say, a pound of uncooked rice contains more than four times as much nutritive material as a pound of raw potatoes. But if we take about 4 pounds of potatoes—that is, the amount necessary to furnish as much nutritive material as the pound of rice—the composition and nutritive value of the two quantities will be just about the same, while from a pecuniary standpoint the advantage would be on the side of the potatoes. The chief difference in the two foods before cooking is that one is juicy and bulky, while the other is dry, and therefore more concentrated. In cooking rice we mix water with it, and may thus make a material not very different in composition from potatoes. By drying potatoes they can be made very similar in composition and food value to rice. Considering the two articles as ordinarily purchased, 4.5 pounds of raw potatoes and a pound of uncooked rice contain nearly equal weights of each class of nutrients and have about the same nutritive value.

COOKING.

In cooking, the heat affects the various constituents of the potato in different ways. The water expands into steam, part of which evaporates from the surface. Within the minute cells making up the tuber it presses so hard against the walls that the tough cellulose is ruptured just as any air-tight vessel may be broken by the pressure of expanding steam. The starch grains inside the cells are thus released, some of them being also disintegrated, while part are changed into the soluble form of dextrin by the heat and part are filled with water or hydrated. The protein coagulates or hardens much as the white of egg does in boiling, and at least a part of it is broken down into simpler bodies. The mineral salts are probably little affected, but some of them are broken down, part of their constituents passing off as gases and part forming new compounds with quite different characteristics. It is the sum of these and minor changes which make the difference between a raw and a cooked potato. As may be seen from the figures in Table 1, the cooked potatoes which contain no added fat or other material do not differ much from the raw as regards composition. The effect of cooking on the mechanical condition of the potato cells is shown in figure 3.

The figures show the great changes in the mechanical condition of the potato flesh under the influence of heat, the broken cell walls and the increased bulk of the starch grains being particularly noticeable.

The mealy, soft, porous, cooked potato is in a favorable condition for the action of the digestive juices, as moisture readily penetrates to all parts of it, while this is not the case with the raw and rather tough flesh of the uncooked tuber. It is commonly said that raw starch, like that found in the potato, is not digestible, but later investigations indicate that this is not the case and that the digestive juices will dissolve the starch, provided the cell walls are ruptured so that the ferments may come in contact with it. The fact that some of the starch may be changed to soluble bodies under the influence of heat in cooking is an advantage rather than the reverse from the standpoint of digestion.

One of the great advantages in cooking potatoes and similar vegetable foods is the improvement in flavor. Raw potatoes, especially old ones, often have a decidedly bitter and disagreeable flavor (see p. 20), which is less marked after cooking, as some of the flavor-yielding bodies are volatilized or are extracted. The flavor of the cooked

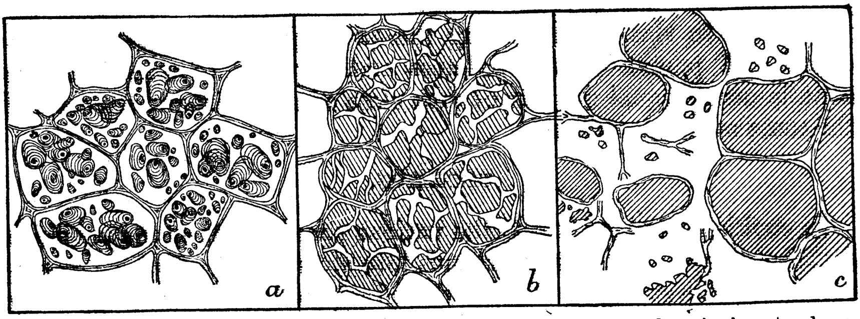

FIG. 3.—Changes of starch cells in cooking: *a*, cells of a raw potato with starch grains in natural condition; *b*, cells of a partially cooked potato; *c*, cells of a thoroughly boiled potato.

potato is also due in part to the development of the cooked-starch taste, which is much more pleasant than that of raw starch.

There are also disadvantages in the results of cooking, and though on the whole they are much less important than the advantages nevertheless they influence the food value. There is some reason for believing that the protein of the potato when stiffened by heat is less easily digested than when raw. A much more serious matter is that considerable quantities of the nutrients may be lost from the potato during cooking. So important is this point that at the Connecticut and Minnesota experiment stations several series of experiments have been made to determine just how much of the various nutrients is thus lost when the potatoes are cooked in various ways. In some of the tests distilled water and in others limewater and alkaline water were used, but the quality of the water seemed to have little influence on the loss. In other experiments some of the potatoes were soaked for several hours before boiling, and it was found that this tripled

the proportion of protein lost and doubled that of the ash. If the potatoes were put into cold water at the start, it was found that they lost almost twice as much protein (15.8 per cent) as when they were plunged at once into boiling water (8.2 per cent). With the cold they lost 18.8 per cent of their ash and with the hot water practically the same amount. It has been suggested that the difference in the amount of protein removed is due to the fact that when the potato is plunged into boiling water the protein near the surface hardens at once and hinders the escape of juices from the interior. When, on the other hand, it is heated slowly much of the juice soaks out before the protein coagulates. On account of these losses in boiling potatoes many persons consider steaming preferable. (See p. 11.)

The tests just described were all made with peeled potatoes, but another series was made with unpeeled ones in which it was found that when boiled in their jackets potatoes lost only 1 per cent of their protein and a little over 3 per cent of their ash, no matter what the temperature of the water was at the start. Almost no starch is removed when potatoes are boiled in their skins, but when peeled the mechanical action of the boiling water wears off the outer surface and in this way as much as 3 per cent of the carbohydrates may be lost.

Evidently, then, by far the most economical way to boil potatoes is in their jackets. When they are cooked this way they should, of course, be thoroughly scraped before boiling and it is a common practice to remove a section of the skin at each end of the potato or to pare a ring around the middle of the tuber so that the moisture may escape and the cooked potato may not become soggy on standing. If they are peeled before cooking they should be placed directly in hot water.

When baked in their skins potatoes probably undergo much the same changes as in boiling, save that they lose practically none of their ingredients except a little water which evaporates through the skin. Some of their moisture changes to steam inside, and unless the potatoes are to be eaten immediately this must be allowed a way of escape through a break or holes made with a fork in the skin, or it will change back to water and make the potato soggy.

When raw potatoes are fried they should be cut into small pieces in order that the heat may penetrate to the interior before the coating of fat on the outside becomes scorched. They lose some water by evaporation and absorb considerable fat. The thinner the pieces the greater will be both these changes. Thus potato chips are found to contain only 2 per cent of water and 39.8 per cent of fat, whereas the raw tubers contain about 78 per cent water and 0.1 per cent fat.

When boiled potatoes are mashed with milk and butter, fried, or prepared in any of the multitudinous ways familiar to good cooks, their

composition will be that of plain boiled potatoes plus the nutrients in the materials added. Purée of potatoes made with milk would make a much better single ration than plain potatoes, because it contains a higher proportion of protein. Salt, pepper, and other seasonings have also a decided value in that they improve the flavor of the potatoes and make them more appetizing. The potato may be prepared for the table in a great many ways, and this is an advantage, as it helps to give variety to the diet.

Grated potatoes are sometimes mixed with yeast and used in place of flour for making a kind of bread, rolls, or other similar food. Many cooks think that starting yeast for bread or rolls with potatoes instead of wheat flour makes a lighter sponge. This may be because the potatoes contain a more favorable proportion of the carbohydrates and other nutrients upon which the yeast feeds than does the wheat flour.

In this country the main test of the cooking quality of the potato is whether or not it yields a light, crystalline mass with almost distinct starch particles, or, in common parlance, its mealiness. Investigations were carried on at the Cornell Experiment Station to learn what it was that produced this mealiness, and the conclusion was reached that it depended mainly on the starch. If this was abundant and evenly distributed throughout the tuber the cells would burst open in cooking and make a light, flaky, uniform mass. If the starch was scanty in any part of the potato, water would be likely to settle there and make the cooked potato soggy. Mature but still fresh tubers hold more starch than either young or long stored ones as we have already seen, and the inner medullary layer is more likely to be poor in starch than the outer layer. Therefore the tubers most likely to cook into mealiness are the well-developed crisp ones. When the tubers are young or watery, or have a large core with many long arms branching into the outer medullary section, they are not so likely to be mealy when cooked.

This, however, does not tell the whole story. Anyone who cares for early spring potatoes knows that there is a quality between sogginess and mealiness which is very satisfactory and which is commonly described as waxiness. In many parts of Europe this condition is generally preferred and is considered a mark of excellence. While mealiness depends on starch and sogginess on water content, waxiness, according to the French authorities, Coudon and Boussard, depends on the proportion of protein to starch. If the protein is sufficiently abundant, it will as it hardens in cooking form a sort of waxy framework in which the starch will be lightly held together instead of separating into distinct flakes as in mealy potatoes, where there is not enough protein present to resist the pressure of the starch. Such

waxy potatoes retain their shape better than the mealy ones and are more suitable for garnishing meats for salad making and for the preparation of many fancy dishes. As has been shown, the proportion of protein to starch is greater in young than in mature tubers, and therefore, in American potatoes at least, the early varieties are most likely to have this waxiness. In point of flavor there is almost as much difference as in consistency, as the nitrogenous tubers usually contain also a larger proportion of acids and perhaps sugars and solanin (see p. 19) than the starchy.

DRIED OR EVAPORATED POTATOES AND CANNED POTATOES.

Potatoes are so valuable in the diet that many attempts have been made to put them into a compact form in which they can be kept for a long time. This is usually accomplished by drying them, which both preserves them from decay and reduces their bulk. One of the oldest of such preparations is one long used in Peru and known as "chunno." To make it, part of the juice is pressed out of the potatoes, which are then dried in the air until they are reduced to about one-fourth of their original weight. There is a variety of similar preparations in American and European markets, and although the mode of procedure differs considerably in the various brands the main principle is the same, namely, to check bacterial action. The changes which we call decay are caused mainly by the development of bacteria. These can reproduce only where there is moisture and warmth present. Therefore, if the moisture is removed, their growth is retarded. The fact that the bulk of the potatoes is reduced at the same time is especially advantageous because such dried preparations are used mainly for camping expeditions, long sea voyages, and under other conditions where storage space is at a premium. The composition of such desiccated or evaporated potatoes is practically that of the original tubers minus more or less of the water. (See Table 1, p. 10.) Of course if extreme heat is used in the preparation, part of the starch may be changed to dextrin and there may be other minor changes in the chemical composition. There is no reason to suppose that these decrease the nutritive value. Various kinds of desiccated potatoes have been studied at the California Agricultural Experiment Station. Their water content ranged from 4.8 to 7.9 per cent, and their total carbohydrates from 77.9 to 80.6 per cent. In fact, their general composition was not unlike that of good white flour. They contained slightly less water, protein and fat, slightly more carbohydrates, and noticeably more mineral matters. Of course desiccated potatoes are supposed to be soaked in water before using and in this way regain somewhat their original characteristics. While their flavor and appearance can not

equal those of good fresh potatoes, they are considered very appetizing and acceptable where fresh ones are unobtainable.

Chemical substances are sometimes used for improving the color (i. e., "bleaching") of desiccated potatoes. While a small quantity of these may be harmless, their continued presence in the diet might be very dangerous, and their use is not to be recommended.

Canned potatoes are on the market and are prepared for use in camps or wherever it is not convenient to cook food. They also may be kept in good condition for a long time. In composition such goods do not differ from similar freshly cooked potatoes.

STORAGE: ITS EFFECT ON QUALITY.

It is a fact of common experience that potatoes suffer more or less change during storage. If the tubers were originally diseased, the rot or other disease will go on developing until the potatoes are quite unfit for food, or if they have been bruised and are stored in a very warm, moist place, the injured portion offers an entrance to micro-organisms and bacteria may develop in them and produce decay. But aside from these abnormal changes, there are others which occur under the best of conditions. Everyone knows how potatoes shrink and change their flavor as the winter grows late. The water tends to evaporate, and this is accompanied by certain chemical changes within the tuber. The potato, it must be remembered, is not a dead thing, but one in which active plant life is waiting to be renewed as soon as conditions are favorable. Even during the latent winter period the protoplasm of the cells is constantly producing minute changes in which part of the sugar is broken down and carbonic acid and water are given off. Part of the insoluble starch is also changed into dextrin and other soluble forms. This is believed to be due to the action of ferments normally present, which aid the plant by thus changing its stored food into a form in which the protoplasm can use it for new growth. The extent of these changes seems to depend on the age of the tuber and the temperature at which it is kept. The older it is the more ready it will be to begin its new growth and the more abundantly will the starch be converted into sugars. This explains why old potatoes are less starchy and mealy and sometimes sweeter than fresh ones. The temperature affects especially the activity of the protoplasm and the production of water and carbonic acid from the sugar, and thus it is that potatoes stored in a warm place are more likely to shrink than those in a cool place. These facts also suggest why frozen potatoes have such a sweet taste; the change of starch into sugar by the enzyms goes on regardless of the cold, but the activity of the cell protoplasm is checked by the cold and instead of being broken down the sugar accumulates. The sweet taste is

more noticeable in tubers which have been slowly frozen than in those subjected to a sudden cold because the sugar has had a longer opportunity to form. If frozen potatoes are left for a few days in a moderate temperature, part of the sugar will revert to starch and the sweet taste in a measure disappear, but such potatoes never wholly regain their original flavor. Of course the amount of material which is broken down during storage will vary with the conditions, but sound potatoes properly stored should not shrink more than 10 or 12 per cent. The most favorable temperature for keeping potatoes is from 32 to 50° F., and if the storeroom is dry, well aired, and partly lighted, they are less likely to be attacked by disease or harmful bacteria.

Toward spring, or, if the tubers are old, even during the winter, potatoes begin to show signs of new growth, no matter how carefully they have been stored. Of course after the sprouting begins, the chemical changes take place very rapidly and the quality of the potatoes for food falls off decidedly. The reserve starch is drawn on by the growing shoots and with it goes the "mealiness."

POSSIBLE DANGERS FROM EATING POTATOES.

As has already been pointed out (p. 7), potatoes, when first introduced into Europe, were regarded as poisonous. This prejudice was soon overcome and the fact generally recognized that under ordinary circumstances potatoes are unquestionably wholesome food. Occasionally one hears of a person who is made ill by eating potatoes just as some are made ill by milk, by strawberries, or other food. Such cases are rare and due to individual idiosyncracy. Reference can not be made here to diabetes or other conditions of ill health in which potatoes and similar starchy foods are not permitted, since this is a subject which pertains to the practice of medicine rather than to a discussion of dietetics.

Cases of actual poisoning from potatoes are not unknown, and perhaps, without exception, have been found to be due to an abnormal solanin content such as is found in sprouted tubers, in very old potatoes, and in potatoes which have turned green on exposure to the light. Solanin is a characteristic constituent of potatoes and other plants of the same family. It is acrid in taste and is poisonous. Only a trace, however, about 0.01 per cent on an average, is found in the tubers of the varieties which are grown for the table, and this quantity is far too small to cause any unpleasant symptoms. It is claimed that the characteristic flavor of potatoes is due to this mere trace of solanin. At any rate, the very starchy potatoes which are lacking in flavor contain only about half as much solanin as the better table varieties. Potatoes which have grown on the surface of the ground or which have been

exposed to the light frequently turn green, and such tubers contain abnormal amounts of solanin, as do old and shriveled potatoes which have sprouted. It is best not to use such old potatoes, but if they are eaten the flesh around the sprouts should be cut away, as this portion is particularly liable to contain solanin. Small or unripe tubers contain a higher percentage of solanin than full-grown tubers.

Analysis has shown that wild potatoes contain practically the same kind and proportion of nutrients as the cultivated varieties. The solanin content, however, is very considerably larger, 0.3 per cent having been found. These wild potatoes when cooked are slimy and almost translucent and entirely inedible.

MARKS OF GOOD POTATOES.

Appearance, taste, and consistency are the points by which we judge a cooked potato. Unfortunately it is not always easy to tell from their appearance which raw potatoes will prove the best, but there are certain marks which aid in making a choice.

The early varieties and young potatoes generally are preferable to more mature ones in point of flavor. Such tubers usually have a smoother skin than older ones. They are not as mealy, however, and do not keep as well. Late in the season, therefore, well developed tubers are safer. Very large ones are not especially desirable, partly because it is hard to cook them evenly and partly because they are often very variable in texture. Smooth, regularly shaped tubers with comparatively few eyes are more economical than irregular ones which can not be peeled without undue waste. In this country white or creamy-fleshed varieties are preferred, but in Europe yellow-fleshed varieties are most esteemed.

Different varieties may have distinct flavors, but the soil and climate in which they are grown and the fertilizers used cause such great variations that variety alone is no sure guide. Age is by far the most important point in determining flavor. The early varieties usually contain a larger proportion of mineral matters, acids, and protein, and therefore have a richer flavor, as has already been said. Tubers old enough to sprout begin to develop an acrid taste, due in part at least to an increased solanin content, which makes them less desirable. (See p. 19 also.)

Watery potatoes are always undesirable because they become soggy in cooking. Young tubers are more juicy than mature ones but their juice often holds so much more protein in solution that they cook with a pleasant waxy consistency. A good mealy potato should feel firm when pressed in the hand. If cut, it should separate crisply under the knife and be of even density throughout. If the core is large and soft, it will make a soggy mass full of holes in the center when cooked.

DIGESTIBILITY OF POTATOES.

In spite of the fact that potatoes are eaten by all sorts of people the world over and are generally conceded to be healthful as well as palatable, one occasionally hears it said that they are unwholesome. It has already been shown how little basis there is for the statement that they contain large quantities of cellulose and how much the danger of solanin poisoning is sometimes exaggerated. Better proof of their wholesomeness and digestibility than the facts of universal experience might seem superfluous. Still, much careful experimenting has been done to determine how much of each of the nutrients can be readily utilized by the body and the general effect of potatoes in the diet. Of course the real nutritive value of any material depends on the amount of nutrients which the digestive organs can make available for the formation of body material or the production of energy for its activities, rather than on the gross amount consumed. Almost the earliest digestion experiments with potatoes were made twenty-five or more years ago in Germany by Rubner, who experimented with a man accustomed to eating large quantities of potatoes, and kept him for two days on a diet of boiled potatoes, eaten either plain with salt or with oil and vinegar as a salad. As is common in such tests, he measured and analyzed the bodily excreta during the experiment, deducted the nutrients appearing in them from the amount consumed in the potatoes and let the difference between the two represent the amount available to the body. Such a diet is of course very irksome to a person accustomed to a more varied one, and it could hardly be expected that even with a subject used to large quantities of potatoes the digestive organs would do their work to the best advantage and it is not surprising to learn that there was some digestive disturbance. Nevertheless, 92.4 per cent of the carbohydrates and 67.8 per cent of the nitrogen were utilized by the body. In later experiments by Constantidini, the potatoes were made into a purée with milk and butter and in this more palatable diet 80.5 per cent of the total nitrogen was utilized and 99.5 per cent of the carbohydrates.

In Russia similar experiments were made, in which first a mixed diet and then potatoes alone were fed to healthy men. Here again 93 per cent of the carbohydrates were found to be digestible, but only 59 per cent of the protein. Later German experiments indicated a more thorough digestion of protein. Experiments have also been made under the auspices of this Department at the University of Minnesota. In these a mixed diet of eggs, milk, and cream, together with large quantities of potatoes, was given to a healthy young man for four days. The digestibility of the eggs, milk, and cream was already known and the digestibility of the potatoes alone was calculated by difference. Of the protein furnished by potatoes 71.9 per cent was

utilized by the body and 93 per cent of the carbohydrates. A series of similar experiments with three men living on a mixed diet, including large quantities of potatoes and other vegetables, was made at Wesleyan University. In this series there was considerable variation in the digestibility of the protein by the three subjects, the results being, respectively, 93.5, 78.5, and 44.7 per cent. There was less variation in the digestibility of the carbohydrates, the figures being 99.9, 99.2, and 98 per cent. The average digestibility of protein in these experiments was 73 per cent, and of carbohydrates 99 per cent. The discrepancies between the results obtained by the different investigators are doubtless due to differences in method and to individual peculiarities of the subjects.

The experiments above described tell nothing of the ease or quickness of digestion. Little information is available on this point regarding any kind of food. In Beaumont's famous observations on a French-Canadian trapper with a gunshot wound in his stomach, roasted or baked potatoes were found to pass through the stomach into the intestines in about two hours, and boiled potatoes in three hours. Bread required three hours. The digestion of carbohydrates (the most important nutrients in potatoes) is accomplished mainly in the intestines, so that such data have very little practical value. To the ordinary healthy person it probably makes little difference whether within reasonable limits his food digests slowly or quickly, provided it digests normally.

There is practically no reliable evidence as to what form of cooking makes potatoes most digestible, but what little there is suggests that the differences between the various methods are slighter than is commonly supposed. It seems probable that well-cooked mealy potatoes in which the starch grains are thoroughly broken open offer less resistance to the action of the digestive juices than ill-cooked soggy ones with the flesh only partially broken down, which enter the alimentary tract in lumps. But how important such differences are no one really knows.

PLACE OF POTATOES IN THE DIET.

When potatoes are selling at 60 cents a bushel, 10 cents spent for them will buy about 10 pounds of tubers. The same sum spent for wheat bread at 5 cents a pound loaf will purchase only 2 pounds of material. At first glance it might seem that potatoes are much cheaper than bread, but they contain so much more refuse, and especially water, than the bread that the 10 pounds furnish only about the same quantities of protein and fat and slightly more carbohydrates than the 2 pounds of bread. Considering that hardly more than one-half of the protein of potatoes is of a kind suitable to build body tissue, it is easy to see why in spite of their cheapness and similar composition they

should not occupy the same place in the diet as bread. A diet of bread alone would be rather too one-sided for the best development of bodily powers, but would come nearer to supplying the required protein without excess of carbohydrates than potatoes alone. According to generally accepted standards, a man at moderately active work requires about one-fourth pound of protein a day, along with sufficient fats and carbohydrates to give the total food an energy value of about 3,500 calories. It would take about 9 pounds of potatoes to furnish this energy, but that amount would yield only about 0.12 pound of true proteid, or one-half of the amount called for by the standard. About 19 pounds of potatoes would be needed to yield the required 0.25 pound of true proteid, an obviously impossible bulk for a day's ration. The "potato belly," often spoken of as occurring among the European peasants accustomed to eating large quantities of potatoes, represents the attempt of the body to adapt itself to such conditions by distending the stomach and bowels. Except under the stress of necessity, however, no one lives entirely on potatoes. Ordinarily they are eaten with other foods rich in protein, such as meat, milk, eggs, etc., and thus supplement these nitrogenous foods by furnishing the needed carbohydrates. Their abundant mineral matters are also valuable in aiding the processes of digestion, and are supposed to prevent scurvy. As was stated above, their carbohydrates are very thoroughly digested. They are easy to cook, and can be prepared in so many ways that they add variety to the list of vegetable dishes, especially in winter, when green vegetables are not common. They have a mild, agreeable flavor acceptable to almost everyone, but which is not sufficiently pronounced to become tiresome. Owing to the ease with which they are grown and their abundant yield, they sell at a price within the reach of all.

Considering all these advantages, it is not surprising that in the temperate regions of Europe and America they rank next to the breadstuffs as a source of carbohydrates in the diet.

CETEWAYO, OR ZULU, POTATOES.

The Cetewayo, or Zulu, potato, a wild variety of *Solanum tuberosum* found in Africa, is sometimes grown as a garden vegetable for its flavor and novelty. It has practically the same percentage composition as the ordinary potato. When cooked, the flesh is purple in color, but when brought in contact with vinegar, as in salads, it turns red.

SWEET POTATOES.

The plants which we know in the United States as sweet potatoes are known to the botanists as *Ipomœa batata* or *Batatas edulis* and are probably natives of the Malayan Archipelago. They were introduced

into Europe earlier than the white potato and were formerly so commonly grown in the warmer countries of Europe that when the white potatoes supplanted them the latter took their English name from a corruption of the usual European name of sweet potatoes—batates. Since then, however, they have fallen into disfavor in Europe, being considered too sweet to be used as vegetables and not sweet enough to fill the place of cakes, sweet fruits, etc. The few that appear in European markets come mainly from southern Spain, northern Africa, or the Canary Islands, and are rather poor in quality.

There are many cultural varieties of the sweet potato, which differ in color, size, and other characteristics of the tuber.

The Chinese and Japanese use one or two varieties similar to those grown in the United States, and others are said to be grown in the Pacific islands, but the chief present home of the sweet potato is the warmer regions of North and Central America and the West Indies. In the Southern States they play almost as important a part as the white potatoes do in other parts of the country, and they have almost usurped the name potato. They are also sometimes called yams, a name which really belongs to an entirely different order of plants, hardly known outside of tropical countries (see page 32). "Yam," however, is not applied so much to the dry, starchy varieties which are demanded by Northern markets as to the sweeter and more juicy kinds preferred in the South. The edible portion of the sweet-potato plant is not an underground stem, like the white-potato tuber, but a true root. Its internal structure is more uniform than that of the white-potato tuber, but its rôle in the life history of the plant is much the same—i. e., to act as a storehouse of plant food for the growth and early development of a new crop of plants. Above ground the plant is a vine which occasionally produces flowers (and in warm countries, seeds) resembling somewhat their relatives, the morning-glory; ordinarily, however, it relies on its roots for reproduction. The first touch of frost is fatal to the vines of most varieties, so the cultivation is limited to warm climates where the growth is practically continuous and the plants perennials or to regions where the summer is long enough to insure the ripening of a crop. Some varieties are more resistant to cold than others and are extensively grown as far north as New Jersey.

The color of the sweet-potato skin ranges from light tan to dark brown or red and purplish tones, and the flesh from almost white or pale lemon yellow to a deep reddish orange. The medium and lighter shades are most frequently seen in the Northern markets. The weight of the tubers also varies considerably, but those which are of medium size and of regular shape are to be preferred for the table, as they cook more evenly and may be prepared with less waste.

COMPOSITION AND NUTRITIVE VALUE.

In general chemical composition the sweet-potato root resembles the tuber of the white potato, although there are important differences between them. The average composition of sweet potatoes raw and cooked is given in Table 2, together with similar figures for the white potato.

TABLE 2.—*Average composition of sweet and white potatoes.*

Kind of potato.	Refuse.	Water.	Protein.	Fat.	Carbohydrates.		Ash.	Fuel value per pound.
					Sugar, starch, etc.	Crude fiber.		
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
Sweet potatoes (edible portion)	....	69.0	1.8	0.7	26.1	1.3	1.1	570
Sweet potatoes (as purchased)	20.0	55.2	1.4	.6	21.9		.9	460
Sweet potatoes (cooked)	....	51.9	3.0	2.1	42.1		.9	925
Sweet potatoes (canned)	....	55.2	1.9	.4	40.6	.8	1.1	820
White potatoes (edible portion)	....	78.3	2.2	.1	18.0	.4	1.0	375
White potatoes (as purchased)	20.0	62.6	1.8	.1	14.7		.8	310

The proportion of total sweet potato discarded with the skin as refuse is probably about the same as in white potatoes, and is estimated at 20 per cent. The most noticeable differences between white and sweet potatoes are in the carbohydrates and water. Sweet potatoes contain on an average about 9 per cent less water and 9 per cent more carbohydrates than white potatoes. They also contain as little, or even less, protein; but as the proportion of true proteids is higher than in white potatoes, being about 1.3 per cent, they supply rather more tissue-building material to the body, pound for pound. This advantage, however, is hardly large enough to be of consequence. Nor does the fact that they contain a trifle more fat or ether extract give them a higher value in the ordinary diet.

More important than any of these differences is that in the nature of the carbohydrates. Sweet potatoes contain a slightly larger proportion of crude fiber than white, though the amount is no higher than in most vegetables. As would be guessed from their flavor, they contain considerable quantities of sugar, part of which is cane sugar and part invert sugar or glucose. The proportion of sugar and starch varies with the climate. The warmer the place in which the plant is grown, the greater the proportion of food laid by in the form of sugar. Tropical sweet potatoes sometimes contain almost equal quantities of sugars and starch. Those grown in New Jersey, on the other hand, probably do not average more than 5 or 6 per cent of sugar, or about one-fifth of their total carbohydrates. As sweet potato culture has developed during recent years, certain varieties have been evolved which tend to store more starch even in the South, but climate has so much influence that probably the dry, starchy roots demanded by northern markets

will never be produced south of North Carolina. On the other hand, the sweet, sirupy "yams," prized especially in the South, could hardly thrive, except in the South Atlantic and Gulf States or the extreme Southwest.

When sweet potatoes are first harvested they are left for some time to "sweat," or to lose part of their moisture by evaporation before they are shut up in storerooms. Where they are grown on a large scale they are sometimes "kiln-dried," i. e., placed in a temperature at about 90° F. for a week or more. Ordinarily, however, it is more convenient and quite as desirable to dry them more slowly at a lower temperature. After the "sweating period" they should be stored in a dry, well-ventilated place at a temperature of 50 to 60° F. Little is accurately known about the chemical changes which take place during storage. Almost everyone has learned from experience, however, that late in the season they become watery and sometimes disagreeable in taste, especially if they have been left in a cold place, the peculiar and characteristic flavor often noted being due to a bacterial disease, a sort of dry rot. These undesirable changes may take place at any temperature below 50° F. To avoid the danger of shipping in cold weather, the southern sweet potato crop is usually sent north early in the autumn and stored near the retail market. New Jersey sweet potatoes are often buried in sand for the winter and sold in excellent condition late in the season. Housekeepers should be careful not to keep sweet potatoes in cold, damp cellars; in fact, many consider it safer to buy them in small quantities as needed. In choosing sweet potatoes at the market, firm, fresh-looking ones should of course be preferred to the old and shriveled roots, and medium sized, smooth roots are more satisfactory than very large or very small ones.

Early in the season unripe potatoes are sometimes marketed, and may be recognized by cutting them, as the flesh will soon turn dark green, whereas the properly ripened roots will not change in color.

As is the case with storage, our knowledge of the changes which cooking makes in sweet potatoes is confined mainly to the facts of common experience. There is no reason to suppose, however, that these changes, particularly with reference to the rupturing of cell walls and the swelling of starch grains, due to the absorption of water, etc., differ greatly from those which take place in white potatoes. One point is generally noticeable—the longer the cooking is continued the more moist does the root become. This is probably due to changes in the carbohydrates. Part of the starch is doubtless changed to soluble carbohydrates by the heat and then dissolved in the juice, and the cane sugar is inverted—that is, split up into simpler sugar. The very sweet southern varieties become so moist during baking that a sirup frequently exudes through the skin.

Sweet potatoes may be prepared for the table in many of the ways used for other starchy vegetables, and are also used for many special dishes where their sweet flavor is an advantage. In some parts of Asia they are preserved in sugar much as we preserve fruits.

Directions for cooking potatoes and other vegetables will be found in an earlier bulletin of this series.[a]

DRIED AND CANNED SWEET POTATOES.

Dried sweet potatoes were formerly a domestic product, and strings of them were hung from the rafters along with apples and other dried fruits and vegetables, but in these days of storage warehouses the custom has very largely passed away. Special devices for evaporating sweet potatoes are on the market, and desiccated sweet potatoes are prepared in much the same way as desiccated white potatoes and are sold to some extent. The South Carolina Experiment Station has devoted considerable attention to studying the possibilities of this industry.[b]

Within recent years the practice of canning sweet potatoes has been developed with so much success that it is now an important industry. Medium sized roots are usually chosen for canning, and they are generally put up in 3-pound tins. Canned sweet potatoes have been used in the army ration in the Philippines and are said to be in demand in lumber camps and mining camps. They are also used like other canned vegetables when it is not convenient to depend upon a fresh supply.

Although the bulk of the sweet potato crop is used for human food, some of the coarser kinds are fed to stock and a small part is used for the preparation of sweet potato flour—that is, sliced, dried, and ground tubers—and for the manufacture of starch.

DIGESTIBILITY AND PLACE IN THE DIET.

So far as can be learned, the only digestion experiments which have been made with sweet potatoes are those reported from Japan and quoted at length in a summary of Japanese investigations published by this Department.[c] Judging by these results, 98 per cent of the carbohydrates of sweet potatoes are digested, or about the same as in the case of white potatoes. The values for protein were very variable, but on the whole were lower than for protein of white potatoes.

It is a matter of common experience that sweet potatoes are wholesome and as a rule are digested by the average man without distress. Many persons find the starchy varieties so "dry" that they do not relish them without adding large quantities of butter. This makes a

[a] U. S. Dept. Agr., Farmers' Bul. 256.

[b] South Carolina Sta. Bul. 71; U. S. Dept. Agr., Farmers' Bul. 169, p. 25.

[c] U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 174.

rather rich mixture and is perhaps accountable for the digestive disturbance occasionally experienced.

Considering both composition and digestibility, it may be said that the nutritive value of sweet potatoes is much the same as that of white potatoes and that they are well fitted to occupy the same place in the diet and furnish a palatable substitute for white potatoes. Further, their characteristic and pleasing flavor is an additional advantage. In the North they frequently cost somewhat more than white potatoes, but are still among the cheaper vegetables. In the South they are quite as cheap or cheaper than white potatoes, and merit their extensive use.

THE JERUSALEM ARTICHOKE.

The Jerusalem artichoke (Jerusalem being a corruption of "girasole," the Italian name for sunflower) is a tuber-bearing member of the sunflower family, as its Latin name, *Helianthus tuberosus*, implies, and is entirely distinct from the French or globe artichoke. Many farmers in this country are prejudiced against the Jerusalem artichoke, considering it an undesirable weed, but in Europe, and to a certain extent in the United States, it is believed to be a valuable plant, since the forage may be fed to stock, while the abundant tubers are useful as a vegetable and also for farm animals. In flavor the tubers slightly resemble the globe artichoke, and this doubtless accounts for their name. They contain on an average 78.7 per cent water, 2.5 per cent protein, 0.2 per cent fat, 17.5 per cent total carbohydrates of which 0.8 per cent is crude fiber, and 1.1 per cent ash. In the absence of accurate determinations it may be assumed that the waste in preparing the tubers for the table is the same as in the case of potatoes, namely, 20 per cent. Judged by these values the artichoke tubers are quite similar in composition to potatoes (see page 10). They differ, however, very markedly in respect to the nature of the carbohydrates which are present, inulin and levulin (which are closely related to starch chemically), and a considerable amount of pectose bodies replacing the starch which is characteristic of potatoes. It is owing to the absence of starch that Jerusalem artichokes are included in the vegetables permitted to patients suffering with diabetes. Little is known regarding the digestibility of the typical carbohydrates which these tubers contain, but it is commonly assumed that they do not differ materially from starch in this respect, and common experience has shown that the artichoke is perfectly wholesome and a pleasant addition to the diet, particularly as they are not injured by frost and may be dug in the spring when other fresh vegetables are not very common. As the plant is very prolific and easily grown, the Jerusalem artichoke is not an expensive vegetable.

STACHYS.

This vegetable, known to the botanists as *Stachys sieboldi*, has been introduced into America from Japan and has a number of different names, such as Japanese potato, Chinese artichoke, chorogi, etc., but the name stachys seems to have been adopted as the common one in this country. The plant is a small perennial belonging to the mint family and produces just below the ground a multitude of small white crisp edible tubers varying from an inch to two and one-half inches in length and about one-half an inch in thickness and marked by irregular spiral rings, which give them a corkscrew-like appearance.

Stachys has been tested at the New York (Cornell) and a number of the other agricultural experiment stations, and proved so easy of cultivation and pleasant in taste (the flavor resembling artichokes) that the vegetable has made many friends and is now procurable at the markets in most of our larger cities. The agreeable quality is in considerable measure due to the crispness of the tubers, and as this disappears when they are exposed to the air they should be stored in sand or sawdust. They are ready for use when the plant dies down in the autumn, though they may be easily carried over the winter and are prepared for the table like potatoes or other vegetables, or may be eaten raw like radishes. On an average, stachys has the following percentage composition: 78.6 per cent water, 2.7 per cent protein, 0.1 per cent fat, 17.4 per cent total carbohydrates (0.7 per cent being crude fiber), and 1.2 per cent ash. Like the other roots and tubers which have been spoken of, the stachys is characterized by a high water content, and carbohydrates constitute the principal nutritive material. According to some authorities inulin is present in stachys in place of starch, while others state that starch is replaced by a special carbohydrate called stachyose. A digestion experiment with stachys was made some years ago in Japan[a] and it was found that the carbohydrates were about as thoroughly digested as those of potatoes, 95 per cent being retained by the body.

TROPICAL STARCH-BEARING ROOTS.

In the Tropics a very large proportion of the carbohydrates of the diet of both native and European residents is furnished by starch-bearing roots, such as the cassava, yam, yautia, and taro. None of these are common vegetables in the United States, though some or all are sold in the oriental quarters of our cities and sometimes in a limited way in other markets, and the cassava and yautia are grown to some extent in the Southern States. In Porto Rico and our other island dependencies such starch-bearing roots are very important articles of diet, and as they may be readily shipped in good condition and are

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 171.

known to be palatable and wholesome it seems not unlikely that they may become important additions to the list of starchy vegetables commonly used in the United States.

The percentage composition of sweet cassava and some cassava products, taro, yams, and yautias is given in the following table, together with that of potatoes, for purposes of comparison:

TABLE 3.—*Average composition of some tropical starch-bearing roots.*

Kind of food.	Water.	Protein.	Fat.	Total carbohydrates.		Ash.	Fuel value per pound.
				Sugar, starch, etc.	Crude fiber.		
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
Sweet cassava	66.0	1.1	0.2	30.2	1.8	0.7	610
Cassava starch	10.5	.5	.1	88.8		.1	1,625
Cassava bread	10.5	9.1	.3	79.0		1.1	1,650
Cassava cakes or wafers	10.3	1.1	.2	85.2	1.6	1.6	1,670
Taro	70.9	1.8	.2	23.2	.8	1.2	475
Yams	72.9	1.8	.2	23.3	.6	.9	475
Yautia tubers	70.0	2.2	.2	26.1	.6	.9	535
Potatoes	78.3	2.2	.1	18.0	.4	1.0	375

CASSAVA.

The cassava now being cultivated to a considerable extent in Florida, but rather as a cheap source of commercial starch, glucose, etc., than as a direct foodstuff, is an American plant widely used for food purposes throughout Central America, the West Indies, and the hot regions of South America. There appear to be two principal varieties, the sweet cassava and the bitter cassava, but only the sweet (*Manihot aipi*) is cultivated in the United States. The bitter cassava gets its name from the fact that the raw root contains considerable amounts of a poisonous prussic acid compound, which is volatile and may be removed by cooking, or even, it is said, by exposure to the hot sun. Both varieties are eaten as vegetables, boiled, baked, fried, or cooked in other ways, and by drying and grinding are made into a flour which forms the basis of various sorts of bread and biscuits. Round, thin, crisp cassava cakes are not infrequently on sale in the United States under a variety of trade names and are popular. Cassava starch is made in large quantities in the Tropics and has always been prized as a palatable and valuable food starch.

Judged by the figures given in Table 3, the cassava is as rich in starch as the potato, and like it can be classed as a succulent carbohydrate food. The amount of protein and fat present is very small, while the amount of mineral matter or ash is practically the same as in very many other common foods. The culture and uses of cassava and other related matters have been discussed in a previous publication[a] of this series.

[a] U. S. Dept. Agr., Farmers' Bul. 167.

TARO.

The taro (known botanically as *Caladium colocasia* or *Colocasia antiquorum*), which is so commonly grown for its edible roots in the Tropics, is more familiar to most persons in the United States in one of its garden forms, namely the large-leafed ornamental plant sometimes called "elephants' ears." There are many varieties of this plant, and it constitutes one of the most important starch-yielding foods of native races in southern China, India, the West Indies, etc. It has a rather disagreeable, acrid taste when raw, but this disappears on cooking. The root may be eaten boiled, baked, or cooked in other ways, and a sort of flour is also made from it. The native Hawaiians eat it in the form of poi—a sticky dough-like dish which is allowed to ferment before it is used.

The composition of taro has been studied in connection with the nutrition investigations of this Office at the University of California.[a] As the figures quoted in Table 3 show, it does not differ very materially from potatoes in composition. Judged by a digestion experiment made in Japan,[b] the carbohydrates of taro compare favorably in digestibility with those of other starchy roots, 95 per cent having been assimilated.

YAUTIA.

The yautia, which is closely related to the taro botanically, though it belongs to a different group known as Xanthosoma, is a very important starchy food in the West Indies, where it is known by a variety of names, such as taniers or tannias, cocoes, eddoes, taye, etc. The cultivated varieties do not produce seed, though they occasionally put out abortive blossoms. The plants will thrive in almost any moist region free from frost and produce a large crop of roots in return for comparatively little cultivation. In Porto Rico every small farmer has his plat of yautias, and next to sweet potatoes and yams they are the most important native food crop. The flesh of the different varieties ranges in color from white to deep orange red. Both root stalks and the tubers which grow from them are edible, though the tubers are considered the more tender and of better flavor.

The culture and uses of the yautia and related questions have been discussed in full in a recent bulletin[c] of the Porto Rico Experiment Station.

The thin skin is usually removed before the yautias are cooked, and this entails on an average a loss of about 5 per cent of the total weight of the tubers. Yautias are cooked as a vegetable in many ways like

---

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 68.
[b] U. S. Dept. Agr., Office of Experiment Stations Bul. 159, p. 171.
[c] Porto Rico Sta. Bul. 6.

potatoes, and a starch is sometimes made from them which is used for making puddings, cakes, etc. In connection with the nutrition investigations carried on by the Office of Experiment Stations, a number of tests were made of the culinary qualities of yautias, taro, and yams supplied by the Porto Rico Experiment Station, and it was found that these vegetables could be readily prepared for the table like potatoes in a number of appetizing ways.

YAMS.

The true yams (Dioscorea), which are often confused with sweet potatoes (see p. 24), belong to a group of climbing plants. The number of varieties found throughout the Tropics and subtropics is very large and many of them bear edible starch-yielding roots which vary greatly in size, some being no larger than potatoes and others several feet in length and weighing 30 pounds or more. The true yams are grown extensively in southern China, Oceania, Porto Rico, the West Indies and other tropical regions and are very important sources of carbohydrates in the diet, ranking in Porto Rico, for instance, next to the sweet potato.

When used as a vegetable they are boiled, roasted, or cooked in other ways like the potato, or may be made into a sort of flour and used as a breadstuff. The flours and starches prepared from the yams and other tropical roots of course differ from wheat flour in that they contain no true gluten. The flesh of many of the commoner yams is white, though certain varieties are yellow fleshed and very much like a sweet potato in appearance. In flavor the yam very closely resembles the white potato, and, as may be seen by the figures for average composition in Table 3, also resemble the potato in composition. In the cooking tests already referred to above, some of the yams used were of the large white varieties, weighing several pounds. These were cut in convenient slices, cooked like potatoes, and could hardly be distinguished from them in flavor or appearance. The Japanese investigations noted elsewhere (p. 27) include a study of the digestibility of yams, and 96 per cent of the total carbohydrates was found to be assimilated.

SUCCULENT ROOTS, TUBERS, AND BULBS.

There are a number of common root vegetables which resemble each other in so many points that they may be conveniently grouped together for discussion. Prominent among these are beets, carrots, turnips, parsnips, etc. In many cases the leaves and stems are also used as pot herbs or "greens," especially while they are young and tender. Most of these vegetables have developed from wild forms whose roots are small, tough, and possessed of stronger flavor and

odor than the cultivated varieties. Since earliest times the ordinary succulent roots have been common garden crops. They are cheaply grown in almost any temperate region and are very generally used as food.

There are also a number of these roots grown for the table in Europe and elsewhere which are not often seen in the United States but which agree in general character with those referred to above. Parsnip-chervil, Spanish salsify, and Teltow turnips may be cited as examples. Among the succulent roots used by the Chinese and other Orientals, but not commonly used by western races, may be mentioned arrow-head, sacred lotus, and water chestnut. These were included in a study[a] of Chinese foods sold in this country, which was made at the California Experiment Station in cooperation with the nutrition investigations of the Offices of Experiment Stations.

Of the bulbs used as food in the United States, various members of the onion family are the only ones which need special mention, though lily bulbs of different sorts are eaten by the Chinese and may be purchased in our large cities, and various wild bulbs have always been gathered as food by the Indians.[b]

The following table shows the composition of the succulent roots, tubers, and bulbs commonly used as food, as well as the composition of potatoes, which is included for purposes of comparison.

TABLE 4.—*Average composition of succulent roots, tubers, and bulbs.*

Kind of vegetable.	Refuse.	Edible portion.						
		Water.	Protein.	Fat.	Carbohydrates.		Ash.	Fuel value per pound.
					Sugar, starch, etc.	Crude fiber.		
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Calories.*
Beets, fresh	7.0	87.5	1.6	0.1	8.8	0.9	1.1	215
Beets, cooked	....	88.6	2.3	.1	7.4		1.6	185
Celeriac	20.0	84.1	1.5	.4	11.8	1.4	.8	285
Carrots, fresh	20.0	88.2	1.1	.4	8.2	1.1	1.0	210
Carrots, desiccated	....	3.5	7.7	.6	80.3		4.9	1,790
Parsnips	20.0	83.0	1.6	.5	11.0	2.5	1.4	300
Salsify "Oyster plant"	25.0	85.4	4.3	.3	6.8	2.0	1.2	250
Black salsify	20.0	80.4	1.0	.5	17.1	2.3	1.0	390
Radishes	....	91.8	1.3	.1	5.1	.7	.1	135
Turnips, white	10.0	89.6	1.3	.2	6.8	1.3	.8	160
Turnips, yellow (ruta-bagas)	10.0	88.9	1.3	.2	7.3	1.2	1.1	185
Kohl-rabi	20.0	91.1	2.0	.1	4.2	1.3	1.3	145
Onions	30.0	87.6	1.6	.3	9.1	.8	.6	225
Garlic	....	64.7	6.8	.1	27.9	.8	1.5	650
Potatoes	20.0	78.3	2.2	.1	18.0	.4	1.0	375

As a rule the succulent roots, tubers, and bulbs contain larger quantities of water than the starchy vegetables described in the preceding sections and consequently have a lower nutritive value. The proportion of protein which they contain is low, and of this small

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 68.

[b] U. S. Dept. Agr., Div. Botany, Contrib. U. S. Nat. Herbarium, vol. 7, No. 3.

amount not more than a third, and frequently only a fifth, is in the form of albumin or similar compounds. Various sugars, pectose bodies, and, in some cases, pentosans, very generally constitute the reserve material which the plants store up instead of the starch characteristic of such roots as the potato and sweet potato. As a class these vegetables are characterized by very marked flavors and odors due to the small amount of volatile oils and similar substances which they contain.

Succulent roots, tubers, and bulbs, when considered from the standpoint of the protein, fat, and carbohydrates which they supply, are much less important components of the diet than concentrated cereal foods or even the comparatively succulent starchy roots and tubers. They do, however, furnish some nutritive material, and are appetizing and generally relished, and their use often makes palatable an otherwise comparatively flavorless dish or meal. Furthermore, they contribute bulk to the diet, and this is an important consideration from the standpoint of normal digestion. Perhaps one of the most important functions of these succulent roots, etc., as indeed of most of our common vegetables and fruits, is to supply the body with mineral salts which are needed for the building and repair of tissue, for the proper carrying out of physiological functions, and particularly to insure the alkalinity of the blood.

The ways in which these and other vegetables may be prepared for the table are very numerous and have been discussed in an earlier bulletin of this series.[a]

The various vegetables included in the above table each have some special characteristics which merit discussion and so they will be taken up separately.

BEETS.

Although the greater part of the total crop of beets or beet root, as they are called in Great Britain, is used for the production of sugar or for the feeding of farm animals, yet beets are used in such large quantities as a human food that they rank as one of the most common table vegetables. White or yellow table beets are occasionally to be seen, but the red ones are the most common. The flavor is more delicate in the summer varieties than in the later maturing sorts. Each year the southern-grown beets are becoming more common in our winter market and are superseding the large fully matured roots which were formerly so often stored as winter vegetables and which late in the season often develop a rather bitter and unpleasant flavor. It is sometimes said that beets are more nutritious than turnips, carrots, etc., but a comparison of the values for average composition given in Table 4

[a] U. S. Dept. Agr., Farmers' Bul., 256.

does not substantiate this statement, all these vegetables being very much alike as regards the proportion of nutritive material present.

Cane sugar constitutes a considerable portion of the total carbohydrates of beets, as high as 10 per cent or more having been often reported. Some reducing sugar is also present. In beets grown for sugar making the percentage of cane sugar is considerably higher, sometimes 20 per cent or more, though such high values are the exception. Beets are sometimes said to be very rich in cellulose, but this does not seem to be the case with American varieties whose average composition has been quoted. When beets are cooked the water becomes highly colored, and it is undoubtedly true that a considerable part of the sugar and other soluble nutrients which they contain is extracted, but how much material is removed can not be stated as no cooking experiments with beets have been found on record.

Three digestion experiments were made several years ago at Wesleyan University in which it was found that 72 per cent of the protein, 97 per cent of the carbohydrates, and 90 per cent of the total energy value of the beets were utilized by the body, figures which compare very favorably with those obtained with potatoes in tests made with the same subjects.

Beets are frequently canned at home for winter use and the commercial canned article is a very well-known product. As regards composition, the canned goods have practically the same chemical composition as freshly cooked beets.

CELERIAC.

This vegetable, which is also known as turnip-rooted celery, or knot celery, is closely related to our ordinary celery, being indeed a cultural variety of the same original plant grown under conditions which have developed the root rather than the stalk. In Europe it is by far the most common form of celery, but has never been extensively cultivated in the United States, though it is found in the larger markets. The roots are white and more or less globular in shape, closely resembling turnips in appearance. As the figures in Table 4 show, they have much the same composition as the other succulent roots and tubers. Celeriac has a pronounced celery flavor due apparently to a complex oil like that in the seed, which is rather stronger than that of the tender celery stalks, but when cooked celeriac does not differ very greatly in taste from ordinary stewed celery.

A German investigator has reported mannit, a starch-like carbohydrate, and also small amounts of asparagin, a constituent of asparagus, in tuberous-rooted celery. So far as can be learned no digestion experiments have been made with this vegetable, but it would doubtless differ little in digestibility from beets or other succulent roots.

It is often said that celery is a nerve food, but there seems to be no warrant for such a statement, and the belief is probably a survival of the time when specific virtues were attributed to almost all plants and vegetables.

CARROTS.

Carrots are grown in many varieties, and vary greatly in color, size, flavor, and other characteristics, those most commonly raised for the table being of medium size, deep yellow color, tender, and of delicate flavor. Young carrots are much more satisfactory than old ones, as when fully matured they tend to become hard and woody, especially at the core, while not infrequently the flavor of old carrots is disagreeably strong. Some varieties are more satisfactory than others for winter use, but the winter carrots are, generally speaking, more used for seasoning soups and other dishes than as a table vegetable. Improved methods of transportation, storage, etc., have, moreover, made the small tender southern-grown carrot comparatively common as a winter vegetable.

In composition carrots do not differ very materially from other similar roots, carbohydrates constituting the principal nutritive material. Sugar is an important constituent, 12 per cent or more being sometimes present, though perhaps 5 or 6 per cent would more nearly represent the average. Small amounts of pentosans have also been reported. The proportion of sugar in the carrot, beet, and other vegetables is very variable, being influenced by size, maturity, method of storage, and other factors. Carrots owe their color to the presence of a yellow organic compound known as "carrotin," which is sometimes extracted with the juice and used for coloring butter.

The water in which carrots have been boiled is quite yellow and has a sweet taste, plainly showing that some of the nutrients have been removed in the process of cooking. In order to determine the amount of this loss, experiments were made with carrots at the University of Minnesota, similar to those made with potatoes referred to on page 14. The carrots were cleaned and cut into pieces of various sizes and then boiled in different ways. Whether the water was hot or cold at the start made less difference than in the case of potatoes, but it was found that the more water used, the greater were the losses. On the other hand, the more rapidly the carrots were boiled, the smaller was the loss. Small pieces, doubtless because a relatively large surface was exposed to the action of the boiling water, lost about 30 per cent of their total nutrients, 20 per cent of the true proteids, and 26 per cent of sugar, while large pieces lost only 20 per cent, 5 and 16 per cent, respectively. Figure 4 represents in graphic form the composition of the carrot and the loss of nutrients when boiled.

A European investigator[a] found that when carrots were steamed they became soft a little more quickly than when cooked in hot water and lost considerably less material, as the water over which they were steamed contained only 0.69 per cent of the total material as compared with 3.75 per cent in the case of the water in which they were boiled. The material extracted from the carrots in cooking consisted principally of sugar or similar carbohydrate.

A number of years ago a German investigator studied the digestibility of carrots, and found that about 60 per cent of the protein and 80 per cent of the carbohydrates were retained in the body. His results were too meager to justify general deductions, and it seems probable that the vegetable would, generally speaking, be as digestible as beets or potatoes. Carrots are commonly considered to be wholesome and a valuable addition to the diet, both as a seasoning vegetable and cooked in a variety of ways.

Dried or desiccated carrots are on the market and are recommended for use wherever small bulk and good keeping qualities are important considerations. These goods resemble the fresh carrots in composition, except that they have been concentrated by the evaporation of water.

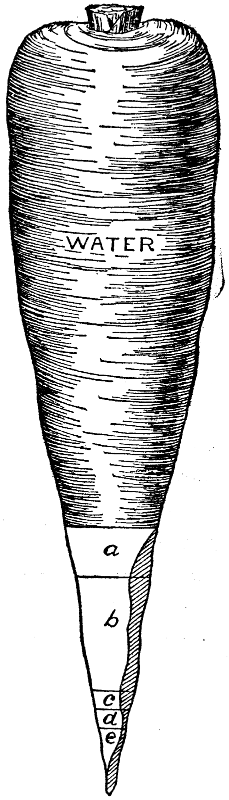

FIG. 4.—The composition of the carrot and the loss of nutrients when boiled: *a*, fiber, starch, fat, etc.; *b*, sugar; *c*, nonproteid nitrogenous matter; *d*, proteid nitrogenous matter; *e*, mineral matter. The hatched portion represents the loss when medium-sized pieces were boiled.

PARSNIPS.

Parsnips belong to the same botanical order as carrots and resemble them in form and general habit of growth. The flesh of the root, however, is paler, being white or light cream color, and the flavor is quite distinct and very pronounced. Parsnips may be kept in the ground over winter and are especially welcome additions to the diet in early spring, when vegetables which have been stored are losing their good qualities. For some reason boiled parsnips were long considered in some regions of Europe to be the proper vegetable to serve with salt fish, but this tradition is not followed in the United States, and they are cooked and served in a variety of ways, as are the other vegetables which they closely resemble.

As regards composition, parsnips are much like the other roots and

[a] Landw. Jahrb. Schweiz., 19 (1905), p. 619.

tubers, but contain rather higher quantities of cellulose, particularly in the core, which becomes stringy and woody when the roots are old. How much of the total nutritive material is lost in boiling is not definitely known, but it is commonly thought to be considerable. The amount is doubtless affected by the same conditions as were noted with carrots. So far as can be learned no digestion experiments have been made with parsnips.

SALSIFY.

The name "salsify" is commonly applied to three distinct vegetables, namely the common white salsify known as "oyster plant" or "vegetable oyster" (*Tragopogon porrifolius*), black salsify (*Scorzonera hispanica*), the schwarz wurzel of the Germans, and the so-called Spanish salsify (*Scolymus hispanicus*). The first of these is very commonly grown in the United States, and black salsify is also grown though less extensively, while Spanish salsify is seldom cultivated. Both common salsify and black salsify closely resemble the other succulent roots used as food in general character. They are not injured by mild frosts and may remain in the ground until late winter or early spring. As the popular name of salsify implies, the flavor suggests that of oysters.

The principal carbohydrate stored in black salsify is inulin rather than starch, and so this vegetable is often used in the diet of diabetics. The proportion of materials lost in cooking and the digestibility have not been made the subject of investigations so far as can be learned, but there is every reason to suppose that salsify would resemble the other succulent roots in these respects.

RADISHES.

The radishes most commonly grown in the United States are those with red exterior and white flesh, although white and dark purple varieties are also well known. Though formerly red radishes were a typical spring vegetable they are now so commonly grown under glass that they are available all winter in large markets. To be at their best, radishes should be eaten before the roots are fully mature and should be very fresh. Besides losing their crispness they become sweeter in taste if they are kept long after they are gathered, owing to the action of a ferment or enzym normally present which changes part of the radish starch to sugar. Similar enzyms are found in beets, carrots, etc., but in these vegetables their action is less marked.

As will be seen from the figures in Table 4, the young radishes analyzed contained even more water than the turnips. The characteristic pungent flavor is due to organic compounds similar to the essential oil of mustard. Radishes are almost always eaten raw, and are so succulent and tender that they are doubtless rather thoroughly

assimilated, though so far as can be learned their digestibility has not been studied. It is frequently said that they are productive of digestive disturbances. Whether this is attributable to the crude fiber which they contain or to the bodies which give the high flavor or to both together it is not possible to say, but such digestive disturbances are by no means general, and when they occur may be due to the fact that succulent foods are frequently swallowed without sufficient mastication.

TURNIPS.

A great variety of turnips is grown throughout temperate climates, some of which being course in texture are used as food for farm animals while other varieties are raised as table vegetables. There is considerable variation in the color, flavor, and composition of the turnip, the yellow-fleshed sorts as a group being commonly distinguished from the white by the name "Swedes" or "ruta-bagas." In the summer the early white varieties are usually preferred in spite of the fact that they are more watery, while in winter the yellow turnips are more commonly used. Solid as the turnip roots appear they contain on an average about 89 per cent of water or a trifle more than is found in whole milk. Only about 20 per cent of the total protein present is in the form of albumin. Carbohydrates are the principal nutritive material, glucose, cane sugar, pectose or jelly-yielding bodies, pentosans, and crude fiber being the characteristic carbohydrates present. The flavor of turnips is due to compounds of sulphur, which are so volatile that when turnips are fed to cows they pass through the body tissues and into the milk and give it an unmistakable flavor of turnips. In cooking, these pungent substances are broken down to some extent and pass off into the air. So far as can be learned no accurate data are available regarding the digestibility of turnips, but they are commonly conceded to be wholesome, palatable, and useful additions to the diet, and there is no reason to suppose that they are not well assimilated.

KOHL-RABI.

Kohl-rabi, or turnip cabbage, represents a curious variety of the turnip and cabbage families in which the reserve material of the plant is stored in a tuber-like enlargement of the stem just above the surface of the soil rather than beneath. Although, strictly speaking, it does not belong to the roots and tubers, it is so similar to them that it has been included in this discussion. Kohl-rabi is considered best in the early summer, when it is still young and tender, but it is commonly found on the market until late fall. In flavor it is more delicate than either turnips or cabbage, though it resembles them more nearly in this respect than it does other common vegetables.

ONIONS, GARLIC, ETC.

The various members of the onion family are so commonly used for flavoring purposes that they should perhaps be included with the flavoring vegetables. Such classifications as those followed in this bulletin are, however, of course, purely arbitrary, and in the case of the onion family some varieties are so largely used as vegetables that it has seemed best to discuss them in connection with the roots, tubers, etc., as they are used in practically the same way in the diet. All the members of the onion family are characterized by very strong flavor and odor, due to the presence of allyl sulphide, a characteristic oil-like organic compound of sulphur. Different varieties of the plant vary somewhat in flavor and composition, and the flavor is usually more abundant in the bulbs or roots than in the leaves or other parts. The flavor-yielding material is very volatile and is broken down by heat to some extent, and consequently the cooked vegetable has a much milder flavor than the raw.

The common onion in its many varieties is the best known and most used in the United States of the onion family. The total crop produced is very large, and quantities are also imported from southern Europe, Bermuda, and the West Indies. As with most vegetables, the young and somewhat immature onions are preferred to the fully matured bulbs, though the latter have the best keeping qualities. White varieties are milder in flavor than the red or yellow sorts and are generally preferred as table vegetables. If they are to be kept through the winter, onions should be taken from the ground as soon as the stalks begin to wither and cured or dried in the air for about ten days. If moist when stored they will not keep well.

The proportion of water and nutrients in onions varies greatly, not only with the variety but with the stage of growth and the method of storing them. Roughly speaking, the chemical composition is very similar to that of the succulent roots also included in Table 4. They contain, however, rather larger quantities of cellulose, particularly in the outer layers, which are usually removed before cooking. The waste in preparing onions for the table may be as high as 50 per cent, but 20 or 30 per cent is perhaps a fairer average. The onions are succulent and tender, and there is every reason to suppose that they are as thoroughly digested as other similar vegetables, though so far as can be learned this question has not been made the subject of definite investigation. They are commonly conceded to be wholesome and have been prized since earliest times as a valuable addition to the diet. The characteristic sulphur compound which they contain is believed to stimulate the flow of digestive juices, and this and other constituents have a desirable effect in overcoming a tendency to constipation. As onions contain no appreciable amount of starch and little sugar they

are usually allowed to invalids from whose diet starchy foods are excluded.

Garlic is a member of the onion tribe, which forms a group of small bulbs called "cloves" in the place of one large bulb, as with the more common varieties of the onion. It is used almost exclusively as a flavoring plant, though some of the mild sorts grown in the Mediterranean region are eaten as a vegetable. In this country it is little eaten save by some of the foreign population, and this is perhaps unfortunate, as rightly used it undoubtedly adds much to the palatability of salads, meats, and other dishes.

Shallot, cibol, etc., are varieties of the onion family much esteemed for their flavor in Europe though they are not common in the United States. Leeks and chives, two other sorts, develop almost no bulbs and are grown for their leaves, leeks being used as a green vegetable or pot herb and chives as a salad plant or for seasoning. Although most families in the United States are familiar with onions only, many good cooks consider that the other members of the group are also indispensable for seasoning purposes.

ROOTS USED AS CONDIMENTS.

Several roots have pronounced aromatic qualities which give them a value quite independent of the nutritive material which they contain. In addition to increasing the flavor of food it seems possible that such condiments may stimulate the flow of digestive juices as well as please the palate. Horse-radish and ginger are the most common condimental roots, though chicory, which is commonly considered in Europe a palatable addition to coffee, may also be mentioned, as well as licorice root and calamus or sweet flag.

Horse-radish is a moisture-loving plant of the mustard family which is cultivated throughout north temperate countries and is very frequently found wild in the United States, as it long ago escaped from cultivation. The root is long, slender, and has a sharp, peppery flavor, owing to the presence of an essential oil which much resembles in general character that in the radish and other members of the mustard family. As regards composition, horse-radish contains on an average 86.4 per cent water, 1.4 per cent protein, 0.2 per cent fat, 10.5 per cent total carbohydrates, and 1.5 per cent ash, and has a fuel value of 225 calories per pound. The root contains a large proportion of water. Starch constitutes the principal carbohydrate present, and, as might be expected from the stringy character of the roots, the percentage of crude fiber is rather high. Though varieties of horse-radish are sometimes cooked as a vegetable, and it is used for seasoning meat, sauces, etc., it is perhaps most commonly used in this country mixed with vinegar as a condiment. It is popularly supposed

that the vinegar softens the crude fiber to some extent and makes it more digestible.

Ginger, the underground root stock of *Zingiber officinale*, is perhaps most commonly used dry as a spice, though the fresh root or green ginger is common in autumn, being used in pickle making, preserving, and in other ways. The young and tender ends of the branching root or rhizome, called ginger buds, are the most delicate portion as regards both texture and flavor. Large quantities of ginger root are preserved in rich sugar sirup, the round stone jars of "Canton ginger" being an old-fashioned confection which is still much prized. The crystallized or candied ginger is even more common and is frequently served as a sweetmeat, and is also used in making deserts of various sorts. While the nutritive value of preserved and crystallized ginger depends, of course, quite largely on the added sugar, the fresh root contains some nutritive material, the average composition being 85.6 per cent water, 1.0 per cent protein, 0.6 per cent fat, 11.4 per cent sugar, starch, etc., 1.0 per cent crude fiber, and 1.4 per cent ash, and has a fuel value of 240 calories per pound. Of the total fat or ether extract, about half consists of the ethereal oil, which together with a pungent nonvolatile constituent "gingerol," gives to ginger its characteristic flavor.

SUMMARY.

The plants which store their reserve material in underground roots, tubers, and bulbs have in many instances come to be regarded by man as among the most important foodstuffs. Cultivation has to a great extent modified the size, structure, flavor, and appearance of the plant parts which are eaten, and the garden varieties are as a rule superior to the wild in these respects and show important modifications in the season of growth and in other ways. As a class the edible roots, tubers, and bulbs may be divided into the following groups: (1) Starch-yielding vegetables, as potatoes and sweet potatoes; (2) succulent roots, as beets, carrots, and parsnips; and (3) condimental or flavoring roots, as horse-radish and ginger. Such plants as garlic and onions might be included in the last group, but are here considered with the succulent roots as some of the milder flavored varieties are eaten in such quantities that they may be fairly considered as foods rather than simply as flavoring vegetables.

As a class the edible roots, tubers, and bulbs have a high-water content and are valued as additions to the diet for their appetizing, succulent qualities and the bulk which they give as well as for the nutritive material which they supply. Starch is the material most commonly stored in these underground receptacles of nutritive material, though it is not infrequently replaced in some plants by inulin, a

closely related body, by sugars of different sorts, pectoses, and other carbohydrates. The proportion of nitrogenous material in such food-stuffs is small, and true albumin seldom constitutes more than a third of the total protein. The proportion of fat or ether extract is also small, being composed in some cases very largely of wax-like bodies found in the skin, or of coloring matter; and in other cases, of volatile oils and similar substances which give the plants their characteristic flavor and odor. The mineral matter or ash is an important constituent of these vegetable foods, the proportion though small being about the same as is found in many other common articles of the diet. Sodium, potassium, and iron salts, and sulphur and phosphorus compounds, etc., are the common ash constituents. As the mineral matters exist in combination with organic acids and other bodies they contribute materially to the flavor of the tubers, roots, etc.

In tropical regions yams, cassava, and other starch-bearing roots seldom seen in northern markets are among the most important vegetables and are cooked and served in a variety of ways. Starch is frequently made from these roots, and they are also used in the production of a sort of meal or flour eaten in large quantities. In temperate and northern regions the potato is the leading starch-yielding vegetable.

The potato varies considerably in composition with age, variety, and conditions of growth. The ripened tubers are usually richer in starch and have better keeping qualities than the immature tubers, but the latter contain larger proportions of mineral matters, acids, etc., and are consequently of richer flavor. Cooking breaks down the cellulose walls of the potato cells which inclose the starch grains, gelatinizes or hydrates the starch so that it becomes softer and looser in structure, and improves the flavor largely by volatilizing acid bodies and similar constituents or otherwise modifying their character. In young tubers, which usually contain a larger proportion of protein to starch than the mature ones, the heat of cooking causes the protein to coagulate or harden around the starch, producing a "waxy" rather than a "mealy" mass. When potatoes are peeled before cooking, some nutritive material is usually removed with the inedible skin, the total material removed (designated refuse in food analyses) being on an average 20 per cent. When potatoes are cooked some water is usually lost by evaporation, and the loss of nutritive material may, under certain circumstances, be also quite considerable. Thus, when potatoes were peeled and soaked before boiling the loss of food material has been found to be, in round numbers, as much as 7 per cent of the total dry matter. Much smaller quantities are lost if the potatoes are not soaked, and when they are baked or boiled in their jackets the loss of nutritive material is insignificant. During storage potatoes lose water by evaporation, and this loss may be so great that the tubers become

shriveled. Some of the starch which is present is changed to sugar, especially if the tubers are frozen or if they begin to sprout. Minute quantities of a poisonous substance of very pronounced flavor, solanin, are found in potatoes, and to this constituent they very largely owe their characteristic flavor. In old or sprouted potatoes the amount of solanin may be great enough to cause illness. When such tubers are used for the table, the flesh around the sprouts should always be carefully cut away, as this is more likely to contain solanin than any other portion. Under ordinary conditions the chance of any injurious effects from solanin in potatoes is very remote, and they are generally conceded to be among the most wholesome and useful starch-yielding foods, particularly when it is remembered that digestion experiments have shown that the starch and other nutritive material which they supply are very well assimilated by the body. Although they contain too small a proportion of the tissue-building proteid in proportion to their carbohydrates to provide a satisfactory ration if used alone, they are admirably fitted for combination with milk, meat, eggs, and other proteid foods to form a palatable well-balanced diet.

Sweet potatoes are common starch-yielding vegetables throughout the United States, and the proportion eaten in the Southern States, where the bulk of the crop is produced, is much greater than in other localities. Much of the reserve carbohydrates these tubers contain is in the form of sugar. In the South varieties so rich in sugar that they become sirupy in cooking are considered superior, but in the northern markets the starchy sweet potatoes are preferred. Some varieties of sweet potatoes are frequently called yams, but this name properly belongs to a distinct order of tropical plants which yield edible tubers, some of them of very large size and others closely resembling sweet potatoes in form and appearance, though they lack the characteristic sweet flavor.

Beets, carrots, parsnips, salsify, turnips, and onions are the most common of the so-called succulent root crops used as food. They differ from the starch-yielding vegetables like potatoes mainly in containing a larger proportion of water, 85 to 90 per cent on an average, and consequently a smaller proportion of nutritive material. Furthermore, it is generally true that starch is not the characteristic carbohydrate of these vegetables, its place being taken by sugars of different sorts, pectose bodies, and other similar carbohydrates, while the percentage of crude fiber is also rather higher than in the edible starch-yielding roots and tubers. Many of the vegetables included in this group are characterized by marked flavors and odors due to the presence of volatile organic sulphur compounds in their juices. In the members of the onion tribe these are especially strong, and some varieties are used almost exclusively as flavoring materials,

while other and milder sorts are also used in large quantities as table vegetables.

Though not very nutritious in proportion to their bulk, root crops as a class offer some advantages over most other vegetable foods. They are so easily grown and are so productive that under ordinary conditions they sell at prices within the reach of all. Many of them may be kept over winter in such good condition that they are never out of season. The carbohydrates, the principal nutritive mateiral present, are in forms which are readily and well assimilated. The characteristic flavor which some of these vegetables possess is a decided advantage, as it makes the vegetables palatable and adds to the variety of the diet. Succulent vegetables of all sorts contribute bulk to the diet, and so are valuable from the standpoint of hygiene, as within limits bulkiness is a favorable condition for normal digestion and also of importance in overcoming a tendency to constipation. In addition, the mineral salts which they contain serve an important purpose in helping to maintain the alkalinity of the blood and have other physiological uses.

O